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For: Inner Elongated Structure of the Roll of a Paper/Board Machine or  
Finishing Machine

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**Marked Up Copy of Substitute Specification under 37 C.F.R. 1.125(b)(2)**

**TITLE OF THE INVENTION**

Inner ~~{e}~~Elongated ~~{s}~~Structure of the ~~{r}~~Roll of a ~~{paper/board-m}~~

Paper/Board Machine or ~~{finishing machine~~

~~{Finishing Machine~~

**CROSS REFERENCES TO RELATED APPLICATIONS**

**[0001] This application is a U.S. national stage application of International App. No. PCT/FI2005/050091, filed Mar. 18, 2005, the disclosure of which is incorporated by reference herein, and claims priority on Finnish App. No. 20045093, filed Mar. 23, 2004.**

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**STATEMENT AS TO RIGHTS TO INVENTIONS MADE UNDER  
FEDERALLY SPONSORED RESEARCH AND DEVELOPMENT**

**[0002] Not applicable.**

## **BACKGROUND OF THE INVENTION**

**[0003]** The present invention relates to the inner elongated structure of the roll of a paper/board machine or finishing machine, such as the shaft of a deflection-compensated roll or the suction box of a suction roll.

5 **[0004]** Current production paper machines run at speeds nearing 2000 m/min and machine widths come close to 11 m. The future development trend is to continue increasing these values.

**[0005]** Increasing both will bring about a changeover to dynamic dimensioning in current deflection-compensated rolls unless new ways are invented for manipulating  
10 the specific frequency of the roll so as to prevent the critical specific frequency from falling upon the running zone. A deflection-compensated roll comprises a stationary shaft and a shell arranged to rotate around it, the shell being supported on the shaft by loading elements which exert a loading force against the inner surface of the shell to load the shell towards the backing roll forming a nip with the said roll. In the  
15 modern, wider deflection-compensated rolls of calenders, it has been necessary to increase dimensioning by as much as four classes as a result of dynamic dimensioning, which incurs considerable additional expenses. The increase in roll mass also causes problems regarding crane capacity, especially in old mills.

**[0006]** In a suction roll, a perforated shell rotates fitted with bearings on thrust  
20 shafts. Inside the shell may be a single- or multi-chamber suction box, the apertures of which open - limited by sealing strips - onto the inner surface of the shell for directing the suction at a specific sector of the suction roll. At the ends of the roll are aggregates by means of which external negative pressure can be connected to the suction box. While the negative pressure is connected, a vacuum is formed under the  
25 paper web through the wire or the felt. The pressure difference formed removes water from the web to the perforations in the shell or holds the web during transfer. The negative pressure in the chambers is determined in accordance with the intended use of the suction roll. A problem with suction rolls is the deflection of the suction

box towards the inner surface of the roll shell while negative pressure is connected to the suction box. In this case, external pressure will deflect the suction box in the direction of its suction inlets, whereby the seals of the suction box are pressed more tightly against the inner surface in the central area of the roll shell, thus wearing the seals more in their ~~centre~~center than on the edge zone.

[0007] In simplified form, the specific frequency of the roll is determined according to the following formula:

$$f_i = \frac{\lambda_i^2}{2 \cdot \pi \cdot L^2} \cdot \left( \frac{E \cdot I}{m} \right)^{1/2}$$

where  $\lambda$  is the support constant  
L is roll width  
EI is stiffness, and  
and m is mass.

[0008] From this equation for specific frequency can be seen that its characteristics cannot be efficiently manipulated by any means other than by manipulating stiffness, when the mass remains approximately constant. Another way of eliminating the detrimental effects of the vibrations themselves is to provide so high roll-internal damping that specific frequencies will not be a disadvantage. The aim of the present invention is to provide a solution by means of which the above-mentioned problems can essentially be eliminated.

[0009] To achieve this aim, the solution relating to the invention for realizing the inner elongated structure of the roll of a paper/board machine or finishing machine is characterized in that the structure is comprised at least partly of composite material, including reinforcing ~~fibres~~fibers in matrix material.

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## SUMMARY OF THE INVENTION

**[0010]** According to a preferred embodiment of the invention, the inner elongated structure of the roll is the stationary shaft of a deflection-compensated roll having a frame part essentially of ~~{fibre-reinforced}~~fiber-reinforced composite, on which  
5 frame part is formed a support part of steel extending in the longitudinal direction of the shaft for supporting the loading elements bearing the shell on the shaft.

According to another preferred embodiment of the invention, the inner elongated structure of the roll is the stationary shaft of a deflection-compensated roll having a frame part essentially of metal, which is coated with

10 ~~{fibre-reinforced}~~fiber-reinforced composite material. According to yet another preferred embodiment of the invention, the structure is a suction box inside the suction roll, which is preferably made completely of composite material.

**[0011]** Composite material refers to a structure comprising reinforcing ~~{fibres}~~fibers, for example, carbon, boron or glass ~~{fibres}~~fibers or their mixtures,  
15 and a matrix material, which may be polymeric, ceramic or metallic. Ceramic material comprises different oxides and carbides, such as Al-, B-, Cr-, Ti-, Si-, Sn-, W-, Zn-, Zr- oxides and carbides or their mixtures, and different nitrides, such as Bn and Si<sub>3</sub>N<sub>4</sub>.

**[0012]** The invention is described in greater detail in the following, with reference  
20 to the accompanying drawings~~{, in which:-~~  
~~t.~~

## **BRIEF DESCRIPTION OF THE DRAWINGS**

~~{Figure}~~[0013] **FIG. 1** ~~{—}~~ shows a prior art deflection-compensated roll as a diagrammatic longitudinal section;

**Figure 2** ~~—~~ shows the roll according to **Figure 1** as a cross-section along line **H-H**;

**Figure 3** ~~—~~;

[0014] **FIG. 2 is a cross-sectional view of the roll of FIG. 1 taken along section line II-II.**

[0015] **FIG. 3** shows a deflection-compensated roll according to the invention as a diagrammatic longitudinal section;

**Figure 4** ~~—~~ shows the roll of **Figure 3** as a cross-section along line **IV-IV**;

**Figure 5** ~~—~~;

[0016] **FIG. 4 is a cross-sectional view of the roll of FIG. 3 taken along section line IV-IV.**

[0017] **FIG. 5** shows the end section of the roll of ~~{Figure}~~FIG. 3;

~~{Figure}~~[0018] **FIG. 6** ~~{—}~~ shows the end section of ~~{Figure}~~FIG. 5 as seen in the direction of arrow **VI**;

~~{Figure}~~[0019] **FIG. 7** ~~{—}~~ shows a diagrammatic longitudinal section of the end section of another deflection-compensated roll realized according to the invention;

~~{Figure}~~~~[0020]~~ **FIG. 8** ~~{—}~~ shows a modification of the embodiment of  
~~{Figure}~~**FIG. 7**.

~~{Figure}~~~~[0021]~~ **FIG. 9** ~~{—}~~ shows a longitudinal section of yet another end  
section of a deflection-compensated roll according to  
the invention.

~~{Figure}~~~~[0022]~~ **FIG. 10** ~~{—}~~ shows a view of the roll of ~~{Figure}~~**FIG. 9** as seen  
from the end with the roll end removed.

~~{Figure}~~~~[0023]~~ **FIG. 11** ~~{—}~~ shows a diagrammatic cross-section of yet another  
deflection-compensated roll according to the  
invention.

**Figure 12** ~~{—}~~.

**[0024] FIG. 11a is an enlarged fragmentary view of the apparatus of FIG. 11  
taken at the circle 11a.**

**[0025] FIG. 12** shows a diagrammatic cross-section of yet another  
deflection-compensated roll according to the invention.

**Figure 13** ~~{—}~~.

**[0026] FIG. 12a is an enlarged fragmentary view of the apparatus of FIG. 12  
taken at the circle 12a.**

**[0027] FIG. 13** shows a diagrammatic longitudinal section of a prior art suction  
roll, and.

~~{Figure}~~~~[0028]~~ **FIG. 14** ~~{—}~~ shows a diagrammatic cross-section of the suction



roll of ~~Figure~~FIG. 13.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

~~{Figures}~~~~[0029]~~ **FIGS.** 1 and 2 show diagrammatically a prior art deflection-compensated roll 10 comprising a stationary roll shaft 11, around which a roll shell 12 is arranged to rotate. The roll shell 12 is supported on the roll shaft 11 by means of hydraulic loading elements 17. The hydraulic loading elements act in the direction of the nip plane, and by means of them, the nip profile of the roll can be controlled in the longitudinal direction of the roll. The roll shaft 11 is connected to the roll's support structures by means of shaft journals 18. In the example disclosed, the roll 10 is provided with slide bearings 14, 14a acting on the main loading plain of the roll, whereby the bearings 14 act in the direction of the nip, that is, in a direction opposite to the loading direction, and the bearings 14a act in the opposite direction with respect to these. The roll further comprises lateral slide bearings 15, 15a, which act in a transverse direction with respect to the main loading direction, and axial slide bearings 16, 16a acting in the axial direction, which rest on the roll ends 13, and 13a, respectively, through a lubricant film. Slide bearings 14, 15, 14a, 15a acting in the radial direction, rest, for their part, against the inner surface of the roll shell 12 through the lubricant film. A roll of this type is known, for example, from ~~{US-patent n}~~**US Pat. No. 5,509,883**, and is thus not described in greater detail in this connection.

~~{Figures}~~~~[0030]~~ **FIGS.** 3 to 6 show a deflection-compensated roll realized according to the invention, where the same or similar parts are referred to by the same reference numerals as in ~~{Figures}~~**FIGS.** 1 to 2. In this embodiment, the roll shaft 11 is comprised of a beam, essentially I-shaped in cross-section, which is made of composite material, preferably of carbon ~~{fibre}~~**fiber** reinforced material, by lamination. In the upper part of the beam 24 is formed a longitudinal groove, in which a support part 26 of steel or cast iron is positioned by means of an intermediate layer. The intermediate layer 25 evens out differences in thermal expansion and fixes the support part to the ~~{fibre-reinforced}~~**fiber-reinforced** frame 11. On the support part 26 are formed bores for hydraulic loading elements 17. Reference numeral 27 denotes a feed pipe for supplying hydraulic medium to the

chamber beneath the loading element 17. On the bottom part of the I-beam have been added ~~{fibre-reinforced}~~fiber-reinforced plates ~~{21-23}~~21, 22, 23 to areas requiring additional stiffness, as determined on the basis of the moment of deflection. The stiffening plates 21-23 can be joined together and to the I-beam, for example, by means of gluing with matrix material or by means of a bolted joint. The I-beam is connected to the thrust shaft 40, for example, in the manner shown in ~~{Figures}~~FIGS. 5 and 6. The thrust shaft 40 comprises an inwards directed roll fixing part 41 to which are formed the protruding ends 11a, 11b of the I-beam, and grooves for receiving the web part between them. The interlocking of the I-beam and the thrust shaft is secured by bolted joints 42, the said bolts extending from the level 43 formed on the upper surface of part 41 to the recesses 45 and 46, the said recesses being arranged to lighten the thrust shaft. Locking may also be carried out, for example, by gluing instead of by bolted joints. The stresses exerted on the joint are not very high because the moment of deflection is small compared with the central part of the beam. This solution makes possible the relatively simple assembly of the roll. Depending on the loading forces, the upper part 24 of the I-beam may also be made completely of steel or cast iron, in which case no separate intermediate layer 25 or support part 26 will be required. An upper part of steel or cast iron may also be fixed, for example, by gluing with matrix material to the ~~{fibre-reinforced}~~fiber-reinforced frame 11. It is also conceivable to make the shaft completely of composite material.

~~{Figure}~~[0031] FIG. 7 shows another deflection-compensated roll realized according to the invention, wherein the frame of the roll shaft 11 is steel and forms an integrated structure with the shaft journal 18. The frame part is lightened in the area between the end sections where it is comprised of a relatively thin support part 11a, which receives the compressive stresses. Nip loads cause compressive stresses on the shaft on the loading element 17 side, and tensile stresses on the lower part. To receive the tensile stresses, between the end parts of the shaft are arranged ~~{fibre-reinforced}~~fiber-reinforced bars or plates 30 running through the end parts and locked in place by locking means 31, which is a locking nut in ~~{Figure}~~FIG. 7.

The bars or plates 30 are preferably of carbon ~~{fibre}~~fiber reinforced composite.

[0032] The embodiment of ~~{Figure}~~FIG. 8 differs from that of ~~{Figure}~~FIG. 7 only as regards the locking means 32, which are made by winding of reinforcing ~~{fibres}~~fibers and by fixing with matrix material to the bar or plate 30.

5 [0033] In the embodiment according to ~~{Figures}~~FIGS. 9 and 10, on the end parts of the roll shaft are formed mounting projections 36, 38, and opposite end parts are joined with each other by means of reinforcing ~~{fibres}~~fibers dipped in matrix material and wound in the longitudinal direction of the shaft, which form bundles 35, 37 of composite material which receive the tensile stresses. Using the mounting  
10 projections makes it possible to wind the reinforcing ~~{fibres}~~fibers into one loop, whereby the strength of the structure is better than when using, for example, the separate locking means according to ~~{Figure}~~FIGS. 7 to 8, where the joint becomes weaker than the basic materials, whereby the structure must be dimensioned according to the strength of the joint. In the solution according to ~~{Figures}~~FIGS. 9  
15 and 10, dimensioning takes place in accordance with the composite material and shaft material, for example, steel or cast iron.

[0034] An additional advantage in the embodiments of ~~{Figures}~~FIGS. 7 to 10 is the free space remaining also on the neutral axis which may be utili~~s~~zed in positioning the hydraulic pipes of the loading elements.

20 ~~{Figures}~~[0035] FIGS. 11, 11a, 12 and 12a show some further embodiments of the deflection-compensated roll according to the invention, with the elimination of disadvantageous vibration as the starting point. This has been reali~~s~~zed by adding a coating 50 of composite material on the existing roll shaft 11. ~~{Figure}~~FIG. 11 shows a diagrammatic, cross-sectional view of a deflection-compensated roll  
25 provided with an almost round-profiled shaft 11, and ~~{Figure}~~FIG. 12 shows a deflection-compensated roll with a so-called movable shell, the shaft of which is essentially rectangular in cross-section. Reference numeral 14b denotes the bearing

means of the roll.

[0036] The coating 50 may be formed, for example, by providing the shaft first with a base treatment, for example, with glue, and by then winding a reinforcing ~~{fibre}~~fiber layer of, for example, glass ~~{fibre}~~fiber or carbon ~~{fibre}~~fiber, around the shaft, and by adding the matrix material to the reinforcing ~~{fibre}~~fiber layer. The addition of matrix material can be carried out, for example, by dipping the ~~{fibres}~~fibers to be wound in matrix material before winding, or by spraying matrix material on the surface of the shaft while winding the ~~{fibres}~~fibers. After coating, bores for the loading elements 17 and bearing elements 14b may be finishing cut on the shaft through the coating, and the means to be fixed on the shaft, such as oil collection means, may be added. Coating made by winding also makes possible relatively easy coating of shafts provided with straight surfaces (~~{Figure}~~FIG. 12).

~~{Figure}~~[0037] FIG. 13 shows a view in principle of a prior art suction roll without an internal suction box. The suction roll comprises a roll shell 111 which is fitted with bearings to rotate on shaft journals 113A and 113B which are connected to the roll shell 111 through end flanges 112A and 112B. The roll shell 111 has a perforation ~~{115}~~comprised of numerous apertures 115 extending through the roll shell 111. ~~{The figure}~~FIG. 13 shows only a part of the perforation~~{115}~~ of the shell 111. At least one of the shaft journals 113B comprises aggregates leading to the interior of the roll, to which an external negative pressure source (not shown~~{in the Figures}~~) can be connected. By means of the negative pressure source, air is sucked out (arrow  $P_2$ ) through the sector formed by the suction box, whereby a corresponding amount of air (arrow  $P_1$ ) will flow inside the roll through the perforation~~{115}~~ of the roll shell.

~~{Figure}~~[0038] FIG. 14 shows the suction roll of ~~{Figure}~~FIG. 13 in cross-section and with the suction box mounted inside it. The suction box 104 and the seal holder part 105 are rigidly fixed to each other. The seals 101 are loaded against the shell 111 by means of loading tubes 103, whereby the seals are made to press against the

shell at approximately constant pressure even when the suction box is in a deflected situation. Because of the seal pressure, water lubrication V is necessary to reduce wear on the inner surface of the roll shell. When negative pressure is switched on in the suction box 104, it deflects towards the inner surface of the shell. Deflection is  
5 strongest in the longitudinal central area of the roll, while the ends of the suction box remain in place. Nowadays, suction boxes are usually made of relatively thin sheet metal, whereby increasing rigidity by increasing thickness would increase weight which is not desirable. The deflection of the suction box can be reduced in accordance with the invention by making, for example, the seal holder part 105 or  
10 the entire suction box 104 of composite material, which makes possible greater rigidity with less weight.

**{Abstract**

**~~The invention relates to an inner elongated structure (11; 104) of the~~**

**{ABSTRACT OF THE DISCLOSURE**

5 **The** roll of a paper/board machine or finishing machine~~{. The}~~ **has an inner**  
**elongated** structure **(11; 104) which** is at least partly comprised of composite  
material, including reinforcing ~~{fibres}~~**fibers** in matrix material. The structure is  
preferably comprised of a combination of metallic material and composite material.